ECONOMIC COMPARISON OF

RELOGGING and CLEAN LOGGING

in mature hemlock

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Table of Contents

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List of Tables

Introduction

Clearcutting mature timber by conventional high-lead methods often leaves considerable volumes of logging residue in the form of tops and small trees. Forest managers in the Douglas-fir subregion of Oregon and Washington are seeking ways to increase forest utilization by developing more economic methods for harvesting this small material (fig. 1). Two such methods being tried are relogging and clean logging. In both methods, an entire setting is clearcut in the usual way. The **relogging** method of this study accomplishes high-lead yarding in two stages, in which the second or relog yarding operation uses the same spar tree but smaller equipment and a smaller crew to achieve lower direct logging costs. The first stage, or main yarding operation, can then concentrate on the large pieces. The **clean-logging** method yards and loads all material, including the small pieces, in a single stage. Both methods employed an extra pulpwood trailer and a loading crib or "sled" at the landing for bundling of small pulp material under 20 feet in length to reduce loading time.

Two methods of relogging were studied. One involved cold decking at the landing; the other "hot" loaded logs as they were yarded into the landing.

Objectives of the study were to determine the most profitable logging procedure and combination of equipment among those tested and to suggest ways for improving efficiency by increasing or decreasing the volumes left for relogging.

Operations were conducted on seven clearcut settings in the Bishop Road area of Weyerhaeuser Co.'s Clemons Tree Farm, near Cosmopolis, Wash., where the company operates a sulfite pulpmill supplied by raw material from the tree farm.

Figure 1.—The Cosmopolis pulpmill provides a market for small pieces and broken chunks. Should they be yarded in the main operation or left for relogging, as shown? (Photo courtesy of Weyerhaeuser Co.)

Procedure

The study was conducted in the spring of 1961 in a 110-year-old mature stand of western hemlock, which included associated species of true firs, Sitka spruce, western redcedar, and Douglas-fir (figs. 2 and 3). Stand conditions were generally uniform among the several settings. Average net volume per acre was 54,000 board feet, including board-foot equivalent of pulpwood. Average area of the settings was 10.4 acres, with a range of 5.7 to 14.0 acres. Elevation was approximately 850 feet above sea level.

The following logging plans outline the three methods of yarding and loading that were tested. Felling and bucking were the same under each plan.

Plan I. Clean Logging (Three Settings)

1. Yarded all material with a 4-inch or larger top diameter, 8 feet or more in length, with regular high-lead equipment and a seven-man crew and two or three chokers. Used standard triple-drum yarding unit mounted on the rear of a crawler tractor (235 horsepower). Yarding labor and equipment cost was calculated as $28.56 per hour.

2. Loaded out all logs over 26 feet in length, plus shorter saw logs, with standard semitrailer log trucks. Used 1-yard loader equipped with tong line.

3. Loaded as many as possible of the pulp pieces into standby sled or separate short trailer when loader was not loading out the larger logs.

Figure 2.—Studies were conducted in 110-year-old stand of mature western hemlock near Cosmopolis, Wash.

Figure 3.—Area on right was relogged soon after main harvest. The older cutting area on the left, not relogged, is in another ownership and was cut about 10 years previously, before development of a pulpwood market.

Plan II.
Relogging Direct to Trucks (One Setting)[1]

1. Yarded, loaded, and hauled out all material down to 10-inch diameter by 26 feet in length, plus any shorter pieces too large for relogging, using a seven-man crew and the same type of heavy equipment as in plan I. Left spar tree rigged for relogging. Yarding labor and equipment cost with this method was $20.67 per hour.

2. Relogged the remaining pieces 4 inches by 8 feet to 10 inches by 26 feet, using light lines, three chokers, a five-man crew, and small triple-drum tractor yarder (125 horsepower).

3. In both stages, loaded concurrently with yarding. Loaded first stage with 1-yard loader. Loaded second stage to sled or short truck and trailer with 3/4-yard loader equipped with tong line or hydraulic tongs. So far as possible, loaded the sled and separate trailer while short truck and trailer combination was making trip to mill yard (fig. 4).

Plan III.
Relogging to Cold Deck (Three Settings)

1. Same as plan II, except that relogging was to cold deck. Loaded out after relogging to cold deck was completed (fig. 5).[2]

[1] Originolly, the study colled for two settings each under plons II ond III; this wos loter modified to occommodote the work schedule of the compony.

[2] One of the three settings in plon III provided relogging doto only. The first-stoge logging had been completed prior to stort of the study.

Figure 4.—An extra 4-wheel trailer cuts loading time in relogging operations.

Figure 5—Relogging employed a 3/4-yard loader and short truck and trailer combination. A loading crib or sled permitted making up partial loads in slack time and further reduced loading time for trucks. (Photo courtesy of Weyerhaeuser Co.)

Measurement of Volume and Area

The volumes removed from each setting were determined from scaling records at unloading points. Separate log brands were used to identify truck loads with their setting. All saw logs were scaled by Scribner log rule. All pulp loads were weighed, with 37 percent of the loads also scaled directly to give weight conversion factors for each setting. Pulp material below saw log size was scaled in cubic feet and converted to cords on the basis of 90 cubic feet per cord, then to board feet at 2 cords per thousand board feet. This corresponds to measurement and accounting practices of the company. The few Douglas-fir and western redcedar logs of less than saw log size were excluded from the study.

The available volume on any setting was considered as consisting of two parts: first, the main volume which would be removed under either method, and second, the extra volume recovered in small pieces by the relogging operation which would not have been recovered by the one-stage clean logging.

A 100-percent inventory was made of logging residue, which included all material down to 4 inches by 8 feet. Standing live and dead trees were tallied if they included material meeting relogging standards.

Area of each setting was determined by photogrammetric methods from large-scale aerial photos taken immediately after logging.

Production Rates

The Weyerhaeuser Co. cooperated in developing daily production rates. In addition to making special arrangements for scaling and recording the output from each setting, the logging superintendent provided a running record of operating times for each crew and for each piece of yarding and loading equipment. Short working delays of less than one-half hour were included in total times used in calculation of daily production rates. Longer delays, such as those for repairs, shutdowns due to dangerous winter weather conditions, or other causes, were excluded.

Development of Cost Data

Unit costs were developed separately for clean logging and for each stage of the relogging method. These costs excluded items that were the same for both methods, such as felling and bucking, road construction and maintenance, fire protection, initial rigging of spar tree, and initial moving in of logging equipment. Hauling costs for the equivalent clean-logging volume were also excluded because they, too, were assumed to be the same under both methods. Hauling cost for the extra volume from relogging, however, was included.

Items of logging burden and administrative overhead were excluded on the assumption that there was no extra expense to the company as a result of relogging. It was considered that the extra work of logging foreman and high climber could be absorbed without employing more men or restricting operations elsewhere.

Hourly costs were developed for yarding and loading operations. These consisted of direct costs for wages, fuel, lubrication, and materials, plus a proportionate share of annual fixed equipment charges for depreciation, interest, taxes, and insurance, prorated on an hourly basis. These fixed costs were included because they are different for the different methods and, in this sense, variable according to choice of method.

Hauling costs for the extra volume from relogging were calculated according to the Washington Utilities and Transportation Commission rates[3], adjusted for defect and profit and risk.

[3] Washington Utilities and Transportation Commission, Tariff No. 4-A. Pp. 34-34A. Olympia, Wash. 1963.

Economic Analysis

Detailed results of this study, in terms of time and production data, are shown in tables 4 through 12 in the appendix. In order to compare the two logging methods on an equal basis, the time and production data were related to a hypothetical 10-acre setting and removal of 50,000 board feet per acre (including pulpwood equivalent). Based on actual production data, clean yarding of all material down to pieces 4 inches by 8 feet (500,000 board feet) would take 12.5 days, exclusive of rigging and unrigging time. Alternatively, under the relogging method, first-stage yarding of material down to 10 inches by 26 feet (434,500 board feet) would take 8.2 days, followed by 6.6 days of relog yarding to a 4-inch by 8-foot minimum size piece (68,600 board feet) plus 0.6 day extra rig-up time. Production rates used in the model exclude data from setting number 7, which had been clean logged prior to decision to relog it for this study. Physical data from this setting, however, are included in some of the appendix tables and are useful to illustrate the sharp drop in production associated with low relog volumes per acre.

Although both the relogging and clean-logging methods were designed to remove material down to a 4-inch by 8-foot minimum, the two-stage or relogging method yielded 0.63 percent more volume, or the equivalent of 3,145 board feet additional for a 500,000-board-foot setting.

Analysis Under Observed Conditions

An economic analysis was made to determine which logging method gave the greatest addition to net revenue after taxes or net extra cost. This amount is composed of two elements: the value of any extra yield produced and any cost saving of one method compared with the other. This net revenue figure takes into account the effect of the 52-percent corporate income tax and a 27-percent capital gains tax saving on the extra volume of wood produced. This capital gains tax saving is the difference between the 25-percent capital gains tax rate and the ordinary 52-percent rate, applied to fair market value minus depletion.[4]

Under average operating conditions of the study and an assumed depletion rate of $1 per thousand board feet and fair market value of $16 per thousand board feet of private stumpage, the relogging method was found to be $130.19 more costly for a hypothetical 10-acre setting than clean logging (table 1).[5]

Unit costs of table 1 are from labor and machine rates and other data, developed in appendix tables 13 through 15. Loading machine rates used in the basic calculations were for crawler-type loaders equipped with tong lines (table 14).

The extra yield from relogging is valued at $18.50 per cord, or $37 per thousand board feet. This represents the approximate cost of purchased pulpwood delivered to the mill. This procedure recognizes that any additional company-produced wood can substitute for purchased wood, which would normally be the most expensive outside wood.

[4] The corporate income tax rate was 52 percent prior to January 1, 1964. This rate was changed to 50 percent from January 1, 1964, and to 48 percent after January 1, 1965. Calculations are shown at the 52-percent rate.

[5] This difference represents the best estimate of the difference between methods. However, due to the small number of replications and the variation in results among the three settings of each method, it is not possible to establish this as a statistically significant difference by the usual standards.

Table 1.—Comparison of costs of relogging versus clean logging, in 110-year-old western hemlock near Cosmopolis, Wash., 1961[1]

Item	Unit cost		Total pertinent cost
	Per hour[2]	Per M bd. ft.[3]	
		Dollars	
TWO-STAGE LOGGING			
Main logging, 434,500 board feet:			
Yarding, 8.2 days x 8 hours = 65.6 hours	28.56	4.31	1,873.54
Loading, 8.2 days x 8 hours = 65.6 hours	15.97	2.41	1,047.63
Relogging, 68,600 board feet:			
Moving in, 0.6 day x 8 hours = 4.8 hours	20.67	1.45	99.22
Yarding, 6.6 days x 8 hours = 52.8 hours	20.67	15.91	1,091.38
Loading, 6.5 days x 8 hours = 52.0 hours	14.11	10.70	733.72
Total pertinent cost	--	9.63	4,845.49
Additional hauling, 3,145 board feet at $6.88 per thousand	--	6.88	21.64
Total costs	--	--	4,867.13
ONE-STAGE LOGGING			
Clean logging, 500,000 board feet:			
Yarding, 12,.5 days x 8 hours = 100 hours	28.56	5.71	2,856.00
Loading, 12.5 days x 8 hours = 100 hours	15.97	3.19	1,597.00
Total pertinent cost	--	8.90	4,453.00
ANALYSIS			
Obtaining extra wood by relogging (two-stage logging):			
Extra cost ($4,867.13 - $4,453.00)			414.13
Income tax reduction (0.52 x $414.13)			215.35
Net extra cost after 52-percent reduction			198.78
Capital gain (3,145 board feet x ($16-$1) = $47.175)			
Saving from capital gains tax, 0.52 x $47.175 = $24.53			
Capital gains tax, 0.25 x $47.175 = 11.79			
Net capital gains tax saving 12.74			12.74
Net extra cost after income tax and capital gains tax			186.04
Obtaining extra wood by purchase (one-stage logging):			
Extra cost of purchased pulpwood ($37 x 3,145 board feet)			116.36
Income tax reduction (0.52 x $116.36)			60.51
Net extra cost of purchasing extra pulpwood			55.85
Comparison of alternatives:			
Net extra cost of relogging			186.04
Net extra cost of purchasing extra pulpwood			55.85
Net extra cost of two-stage logging, instead of one-stage logging and purchase of 3,145 board feet of extra wood			130.19

[1] Includes board-foot equivalent of pulpwood.
[2] Developed from appendix tables 13 through 15.
[3] Derived from total pertinent costs.

More Favorable Alternatives Suggested

Even though daily production in yarding averaged 52,800 board feet in the first stage of the relogging method, it averaged only 10,400 board feet in the second-stage operation as compared with 40,000 board feet for clean logging (table 6). This low production in the second stage was due chiefly to the time lost in road changing (changing of tail blocks and corner blocks for haulback line). It was also due partly to the low relog volume, 6,860 board feet per acre. An additional analysis was made to show the calculated effect of an increase in volume per acre left for relogging (table 2). If twice the volume were left, then the daily production in relog yarding would be increased to 15,800 board feet, and there would be a gain in net revenue of $54.60 per setting over clean logging (table 3, method C).

Table 2.—Comparison of clean logging and relogging under different utilization standards and relogging volumes per acre, in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Method	Minimum utilization standard	Relogging volume per acre[1]	Yield per 500,000-board-foot setting	Number of days per setting[2]		Number of settings per year	
				At average rate	At rate of setting number 3[3]	At average rate	At rate of setting number 3[3]
		M bd. ft.	M bd. ft.				
A (clean logging)	4 inches by 8 feet	--	500	14.0	--	17.1	--
B (relogging)	4 inches by 8 feet	6.86	503.1	7.2	5.6	33.3	42.9
C (relogging)	4 inches by 8 feet	13.7	503.1	9.3	7.7	25.8	31.2
D (clean logging)	7 cubic feet	--	496.6	13.4	--	17.9	--
E (relogging)	5 cubic feet	6.53	499.3	6.2	4.6	38.7	52.2
F (relogging)	5 cubic feet	13.1	499.3	8.8	7.2	27.3	33.3

[1] Includes board-foot equivalent of pulpwood measured in cubic feet.
[2] Includes 1.5 days to move in and rig up for clean logging; 0.6 day for relogging.
[3] Setting number 3 had the most favorable relogging production rate.

Table 3.—Estimated gain or loss in net revenue of other methods over method A, in logging 110-year-old western hemlock near Cosmopolis, Wash., 1961

Method	Gain or loss at average rate				Gain or loss at rate of setting number 3			
	Per thousand board feet	Per setting	Per year	Rate of return[1]	Per thousand board feet	Per setting	Per year	Rate of return[1]
	------	Dollars	------	Percent	------	Dollars	------	Percent
A (clean logging)	--	--	--	--	--	--	--	--
B (relogging)	-0.259	-130.19	-4,335	(2)	0.155	78.08	3,350	5.5
C (relogging)	.109	54.60	1,409	2.3	.441	222.00	6,926	11.4
D (clean logging)	.093	46.27	828	--	--	--	--	--
E (relogging)	-.107	-53.30	-2,063	(2)	.310	154.98	8,090	13.3
F (relogging)	.126	62.90	1,717	2.8	.501	250.17	8,331	13.7

[1] Rate of return on initial investment of $60,930 including relog yarder, loader, landing equipment, rigging, and 24 chokers.
[2] Negative.

Setting number 3 was more favorable for relogging than the average, due chiefly to stand conditions and topography. Production rates of setting number 3 showed a potential gain of $78.08 per 10-acre setting at observed relog volume, or $222 per setting if twice the observed material were left for relogging.

A marginal log study of direct costs and values, conducted concurrently with this study, indicated that material as small as 4 inches by 8 feet would generally be uneconomic by either method.[6] This study did not take into account other reasons that could be advanced for the 4-inch by 8-foot utilization standard, such as reduction of slash hazard, more favorable site preparation for regeneration, a more esthetic appearance of the land after logging, or a condition where raw material supply might be a limiting factor to the company's manufacturing production.

From the data on size distribution of individual logs, a cost comparison was made under the assumption of clean logging to a 7-cubic-foot minimum. This showed a gain in net revenue of $46.27 per 10-acre setting over clean logging to 4 inches by 8 feet (table 3, method D). The two-stage relogging method to a 5-cubic-foot minimum showed even greater potential gains.

The limits of 7 cubic feet under clean logging and 5 cubic feet under relogging represent break-even log volumes, under the conditions of this study, for a yarding distance of 300 feet. Actual break-even log volumes for clean logging and relogging were calculated as 5 and 4 cubic feet, respectively, at 100-foot yarding distance and 10 and 6 cubic feet at 600-foot yarding distance.

Gains of methods D, E, and F of table 3 are not simply due to increased productivity from handling larger material; they are from avoidance of actual net losses in handling uneconomic material.

RATES OF RETURN FROM RELOGGING.—Table 3 also shows calculated rates of return potentially available from an initial investment of $60,930 in relogging equipment. These range from 2.3 percent for method C to 13.7 percent for method F.

COLD VERSUS HOT LOADING.—A comparison was made of yarding and loading production rates with relogging and loading direct to trucks (hot loading), and relogging to a cold deck (table 12). Hourly production in both yarding and loading was greater with hot loading than with cold decking. Some of this difference, however, can be attributed to more volume per piece, more volume per acre, and slightly better ground on the hot-loaded setting.

Average unhooking and loading times for the two methods were:

	Hot loading	Cold decking
	(minutes)	
Unhooking time (per turn)	0.83	1.18
Loading time (per piece)	.85	1.02

[6] Adams, Thomas C. High-lead logging costs as related to log size and other variables. Pacific NW. Forest & Range Expt. Sta., U. S. Forest Serv., Res. Paper PNW-23, 38 pp., illus. 1965.

Conclusions

Forest managers are interested in potential opportunities for increased timber utilization. Economic analysis can provide guidelines to alternative logging methods that promise lower unit costs by employing relatively small equipment and small crews for the smaller logs.

Even though the trial two-stage relogging operations studied were a little more costly than single-stage or clean logging, they provided the data for discovering critical cost factors and for suggesting modified procedures that could be even more profitable. They demonstrate the value of economic analysis that can be tailored to fit the conditions existing on a particular area.

There will be an increasing need for economical logging methods and equipment for handling the increasing volume of small material that will be encountered in western logging operations. The two-stage relogging method is only one alternative. Contract relogging, either by high lead, small tower, jammer, or crawler tractor are other possibilities. Another alternative to be explored is that prelogging of the smaller trees might have resulted in even greater volume recovery, through less breakage, and in lower unit costs.

Where raw material supply is not a limiting factor, some cost savings are possible with even single-stage logging if the minimum utilization standard can be defined more closely and be made more flexible in relation to market requirements.

Appendix

Table 4.—Area, external yarding distance, and volume yarded on study settings in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Setting number	Area	External yarding distance[1]		Volume yarded per acre[2]		
		Maximum	Average	Main logging	Relogging	Total
	Acres	Feet	Feet	M bd. ft.		
Clean-logged settings:						
2	11.4	640	390	--	--	56.4
4	10.7	720	400	--	--	55.7
6	14.0	610	440	--	--	44.2
Subtotal or average	36.1	657	410	--	--	51.4
Relogged settings:						
1	7.6	480	400	44.3	6.4	50.7
3	11.4	550	420	53.4	8.6	61.9
5	5.7	610	410	35.8	6.1	42.1
7	[3](12.3)	[3](740)	[3](540)	--	[3](3.1)	--
Subtotal or average	24.7	527	410	46.5	7.3	53.9
Average	[4]10.1	592	410	46.5	7.3	52.4

[1] Horizontal distance to edge of setting.

[2] Includes board-foot equivalent of pulpwood calculated at 1 cubic foot = 5.556 board feet, from formula: board feet = $\frac{\text{cubic feet}}{90} \times 500$.

[3] Data in parentheses not included in subtotal or averages.

[4] 10.4 including setting number 7.

Table 5.—Machine time and production in yarding on study settings in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Setting number	Machine time[1]			Volume yarded[2]		
	Main logging	Relogging	Total	Main logging	Relogging	Total
	Hours			M bd. ft.		
Clean-logged settings:						
2	--	--	126.5	--	--	642.4
4	--	--	115.5	--	--	595.9
6	--	--	129.5	--	--	618.8
Total	--	--	371.5	--	--	1,857.1
Relogged settings:						
1	59	45	104	336.8	48.8	385.6
3	78	59	137	608.3	97.6	705.9
5	37	33.5	70.5	204.2	34.9	239.1
7	--	[3](61.5)	--	--	[3](38.3)	--
Total	174	137.5	311.5	1,149.3	181.3	1,330.6

[1] Machine time includes operating delays (e.g., hangups, changing guy lines, swinging blocks, moving yarders, and minor delays at the landing). It excludes breakdown time, which in this study averaged 0.0168 hour per hour of machine time. Machine time also excludes time for moving in equipment and rig-up (1.5 days per setting for clean logging and main logging, 0.6 day per setting for relogging).

[2] Includes board-foot equivalent of pulpwood calculated at 1 cubic foot = 5.556 board feet, from formula: board feet = $\frac{\text{cubic feet}}{90} \times 500$.

[3] Data in parentheses not included in subtotals or averages.

Table 6.—Machine production rates in yarding on study settings in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Setting number	Volume yarded[1] per hour			Volume yarded[1] per 8-hour day			Days to yard 500,000 board feet		
	Main logging	Re-logging	Average	Main logging	Re-logging	Average	Main logging	Re-logging	Average
	M bd. ft.								
Clean-logged settings:									
2	--	--	5.1	--	--	40.8	--	--	12.3
4	--	--	5.1	--	--	40.8	--	--	12.3
6	--	--	4.8	--	--	38.4	--	--	13.0
Average	--	--	5.0	--	--	40.0	--	--	12.5
Relogged settings:									
1	5.7	1.1	3.7	45.6	8.8	29.6	11.0	56.8	16.9
3	7.8	1.7	5.2	62.4	13.6	41.6	8.0	36.8	12.0
5	5.5	1.0	3.4	44.0	8.0	27.2	11.4	62.5	18.4
7	--	[2](0.6)	--	--	[2](4.8)	--	--	[2](104.2)	--
Average	6.6	1.3	4.3	52.8	10.4	34.4	9.5	48.1	14.5

[1] Includes board-foot equivalent of pulpwood calculated at 1 cubic foot = 5.556 board feet, from formula: board feet $= \frac{\text{cubic feet}}{90} \times 500$.

[2] Data in parentheses not included in subtotals or averages.

Table 7.—Machine time and production in loading on study settings in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Setting number	Machine time[1]			Volume removed[2]			Volume removed[2] per hour			Volume removed[2] per 8-hour day		
	Main logging	Re-logging	Total	Main logging	Re-logging	Total	Main logging	Re-logging	Average	Main logging	Re-logging	Average
	Hours			M bd. ft.								
Clean-logged settings:												
2	--	--	124	--	--	641.4	--	--	5.2	--	--	41.6
4	--	--	118.5	--	--	592.7	--	--	5.0	--	--	40.0
6	--	--	120.5	--	--	618.0	--	--	5.1	--	--	40.8
Total or average	--	--	363	--	--	1,852.1	--	--	5.1	--	--	40.8
Relogged settings[3]												
1	60	37	97	336.8	47.7	384.5	5.6	1.3	4.0	44.8	10.4	32.0
3	84	69	153	608.3	97.0	705.3	7.2	1.4	4.6	57.6	11.2	36.8
5	38	28	66	204.2	31.0	235.2	5.4	1.1	3.6	43.2	8.8	28.8
7	--	[4](35)	--	--	[4](36.9)	--	--	[4](1.1)	--	--	[4](8.8)	--
Total or average	182	134	316	1,149.3	175.7	1,325.0	6.3	1.31	4.2	50.4	10.5	33.6

[1] Machine time includes operating delays (e.g., waiting for yarder, logs, or trucks). It excludes breakdown time, which in this study averaged 0.00910 hour per hour of machine time.

[2] Includes board-foot equivalent of pulpwood calculated at 1 cubic foot = 5.556 board feet, from formula: board feet = $\frac{\text{cubic feet}}{90} \times 500$.

[3] Settings 1, 5, and 7 were cold-decked settings; setting 3 was hot loaded.

[4] Data in parentheses not included in subtotals or averages.

Table 8.—Pulpwood logging residue, by size class and location, on clean-logged settings in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Location	Setting number	Area, in acres	Diameter, 6 inches and larger				Diameter, 4-5.9 inches only				Diameter, 4 inches and larger				
			Number of logs	Cubic feet	Average cubic feet per log	Cubic feet per acre	Number of logs	Cubic feet	Average cubic feet per log	Cubic feet per acre	Number of logs	Cubic feet	Board-foot equiv-alent per log	Average cubic feet per log	Cubic feet per acre
Off landing	2	11.4	87	420	4.8	36.8	211	359	1.7	31.5	298	779	4,328	2.6	68.3
At landing			26	164	6.3	14.4	9	15	1.7	1.3	35	179	995	5.1	15.7
Total		11.4	113	584	5.2	51.2	220	374	1.7	32.8	333	958	5,323	2.9	84.0
Off landing	4	10.7	61	296	4.8	27.7	159	322	2.0	30.1	220	618	3,434	2.8	57.8
At landing			66	488	7.4	45.6	48	90	1.9	8.4	114	578	3,211	5.1	54.0
Total		10.7	127	784	6.2	73.3	207	412	2.0	38.5	334	1,196	6,645	3.6	111.8
Off landing	6	14.0	206	1,434	7.0	102.4	206	324	1.6	23.2	412	1,758	9,767	4.3	125.6
At landing			23	94	4.1	6.7	37	48	1.3	3.4	60	142	789	2.4	10.1
Total		14.0	229	1,528	6.7	109.1	243	372	1.5	26.6	472	1,900	10,556	4.0	135.7
Total off landing		36.1	354	2,150	6.1	59.6	576	1,005	1.7	27.8	930	3,155	17,529	3.4	87.4
Total at landing			115	746	6.5	20.7	94	153	1.6	4.2	209	899	4,995	4.3	24.9
Total		36.1	469	2,896	6.2	80.2	670	1,158	1.7	32.1	1,139	4,054	22,524	3.6	112.3

Table 9.—Pulpwood logging residue, by size class and location, on relogged settings in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Location	Setting number	Area, in acres	Diameter, 6 inches and larger				Diameter, 4 - 5.9 inches only				Diameter, 4 inches and larger				
			Number of logs	Cubic feet	Average cubic feet per log	Cubic feet per acre	Number of logs	Cubic feet	Average cubic feet per log	Cubic feet per acre	Number of logs	Cubic feet	Board-foot equiv-alent per log	Average cubic feet per log	Cubic feet per acre
Off landing	1	7.6	49	212	4.3	27.9	111	130	1.2	17.1	160	342	1,900	2.1	45.0
At landing			28	115	4.1	15.1	57	88	1.5	11.6	85	203	1,128	2.4	26.7
Total		7.6	77	327	4.2	43.0	168	218	1.3	28.7	245	545	3,028	2.2	71.7
Off landing	3	11.4	26	96	3.7	8.4	63	83	1.3	7.3	89	179	995	2.0	15.7
At landing			8	57	7.1	5.0	35	54	1.5	4.7	43	111	617	2.6	9.7
Total		11.4	34	153	4.5	13.4	98	137	1.4	12.0	132	290	1,612	2.2	25.4
Off landing	5	5.7	17	53	3.1	9.3	113	160	1.4	28.1	130	213	1,183	1.6	37.4
At landing			99	495	5.0	86.8	127	204	1.6	35.8	226	699	3,884	3.1	122.6
Total		5.7	116	548	4.7	96.1	240	364	1.5	63.9	356	912	5,067	2.6	160.0
Off landing	7	12.3	27	112	4.2	9.1	40	58	1.4	4.7	67	170	945	2.5	13.8
At landing			21	141	6.7	11.5	78	106	1.4	8.6	99	247	1,372	2.5	20.1
Total		12.3	48	253	5.3	20.6	118	164	1.4	13.3	166	417	2,317	2.5	33.9
Total off landing		24.7	92	361	3.9	14.6	287	373	1.3	15.1	379	734	4,078	1.9	29.7
Total at landing			135	667	4.9	27.0	219	346	1.6	14.0	354	1,013	5,629	2.9	41.0
Total[1]		24.7	227	1,028	4.5	41.6	506	719	1.4	29.1	733	1,747	9,707	2.4	70.7

[1] Totals exclude data for setting number 7.

Table 10.—Analysis of logging residue on study settings in 110-year-old western hemlock near Cosmopolis, Wash., 1961[1]

Type of logging and setting number	Area	Volume removed	Original volume[2]		Residue off landing		
			Total	Per acre	Total	Per acre	Per million board feet original volume
	Acres	M bd. ft.	— — — M bd. ft. — — —		Bd. ft.	Bd. ft.	M bd. ft.
Clean-logged settings:							
2	11.4	641.4	646.7	56.7	4,328	380	6.69
4	10.7	592.7	599.3	56.0	3,434	321	5.73
6	14.0	618.0	628.6	44.9	9,767	698	15.54
Total or average	36.1	1,852.1	1,874.6	51.9	17,529	486	9.35
Relogged settings:							
1	7.6	384.5	387.5	51.0	1,900	250	4.90
3	11.4	705.3	706.9	62.0	995	87	1.41
5	5.7	235.2	240.3	42.2	1,183	208	4.92
7	[3](12.3)	--	--	--	[3](945)	[3](77)	--
Total or average	24.7	1,325.0	1,334.7	54.0	4,078	165	3.06
Extra volume from relogging	--	--	--	--	--	--	6.29

[1] In pieces 4 inches by 8 feet and larger, off landing, converted to board feet by formula: board feet = $\frac{\text{cubic feet}}{90} \times 500$.

[2] Calculated as sum of volume removed plus total residue on and off landing.

[3] Data in parentheses not included in subtotals or averages.

Table 11.—Production rates in relog yarding and loading, by type of setting, in 110-year-old western hemlock near Cosmopolis, Wash., 1961[1]

Type and setting number	Yarding			Loading		
	Machine time	Production	Production per hour	Machine time	Production	Production per hour
	Hours	— — M bd. ft. — —		Hours	— — M bd. ft. — —	
Cold-decked settings:						
1R	45	48.8	1.08	37	47.7	1.29
5R	33.5	34.9	1.04	28	31.0	1.11
7R	61.5	38.3	0.62	35	36.9	1.05
Total	140.0	122.0	0.87	100	115.6	1.16
Hot-loaded setting:						
3R	59	97.6	1.65	69	97.0	1.41

[1] Includes board-foot equivalent of pulpwood.

Table 12.—Time for changing yarding roads and corner blocks, by type of setting, in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Type and setting number	Area	Volume yarded	Road changes		Corner block changes		Road changes per million board feet yarded		Corner block changes per million board feet yarded	
			Number	Average time	Number	Average time	Number	Time	Number	Time
	Acres	M bd. ft.		Minutes		Minutes		Hours		Hours
Clean-logged settings:										
2	11.4	642.4	18	11.5	6	16.6	28	5	9	2
4	10.7	595.9	21	11.5	4	16.6	35	7	7	2
6	14.0	618.8	60	11.5	9	16.6	97	19	15	4
Total	36.1	1,857.1	99	11.5	19	16.6	53	10	10	3
Relogged settings:										
Main logging:										
1	7.6	336.8	35	11.5	6	16.6	104	20	18	5
3	11.4	608.3	42	11.5	7	16.6	69	13	12	3
5	5.7	204.2	13	11.5	3	16.6	63	12	15	4
Total	24.7	1,149.3	90	11.5	16	16.6	73	15	14	4
Relogging:										
1	7.6	48.8	30	13.2	5	23.3	615	135	102	40
3	11.4	97.6	35	13.2	9	23.3	359	79	92	36
5	5.7	34.9	14	13.2	2	23.3	401	88	58	22
7	12.3	38.3	35	13.2	10	23.3	914	201	261	101
Total	37.0	219.6	114	13.2	26	23.3	519	114	118	46

Table 13.—Yarding cost summary, by type of logging, in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Item	Clean logging and first-stage logging		Relogging	
	Per day	Per hour	Per day	Per hour
	Dollars			
Yarder, 3-drum crawler unit:[1]				
Depreciation @ 15,000 hours	16.08	--	11.36	--
Interest, 6 percent of average investment	4.60	--	3.25	--
Fuel and lubrication	7.67	--	5.97	--
Repairs, 50 percent of depreciation	8.04	--	5.68	--
Taxes, 2 percent of average investment	1.53	--	1.08	--
Subtotal	37.92	4.74	27.34	3.42
Labor:				
7-man crew	144.08	--	--	--
5-man crew	--	--	104.20	--
Payroll overhead (22 percent)	31.70	--	22.92	--
Subtotal	175.78	21.97	127.12	15.89
Wire rope: [2]				
1,000 feet, 1-1/8-inch main line	2.89	--	--	--
1,000 feet, 1-inch main line	--	--	2.33	--
3,000 feet, 5/8-inch haulback	3.20	--	--	--
3,000-feet, 1/2-inch haulback	--	--	3.00	--
3,000-feet, 3/8-inch straw line	.78	--	--	--
3,000 feet, 5/16-inch straw line	--	--	.69	--
Straps	.42	--	.42	--
Chokers, 7/8-inch	4.26	--	--	--
Chokers, 3/4-inch	--	--	1.64	--
Guy lines	1.20	--	.86	--
Subtotal	12.75	1.59	8.94	1.12
Blocks:				
Butt rigging, shackles, fire tools, fuel tank, sled, signal unit, powersaw	2.04	.26	1.93	.24
Total yarding cost	228.49	28.56	165.33	20.67

[1] Clean logging used a 235-horsepower torque converter crawler tractor, estimated delivered price, new, $42,700. Estimated used price (one-third of new or $14,233) plus 3-drum yarding winch ($19,225) minus 10-percent salvage value = $30,112, amount to be depreciated.

Relogging used a 125-horsepower crawler tractor, estimated delivered price, new, $30,815. Estimated used price (one-third of new or $10,272) plus 3-drum yarding winch ($13,350) minus 10-percent salvage value = $21,260, amount to be depreciated.

All calculations are based on 240 operating days per year.

[2] Estimated life of main and haulback lines is 9 million board feet or 225 days (1,800 hours) at 40,000 board feet per day. Estimated life of straw line is approximately 2 years (480 days); straps, approximately 1 year (240 days). Estimated life of 7/8-inch chokers, 15 days, and 3/4-inch chokers, 30 days, with salvage of half the ferrules and hooks. Guy lines valued at half new value, with 5-year life.

Table 14.—Loading cost summary, by type of logging, in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Item	Cleon logging ond first-stoge logging		Relogging	
	Per doy	Per hour	Per day	Per hour
	Dollars			
Looder, crowler unit with heel boom and tongs:[1]				
Depreciotion @ 20,000 hours	17.13	--	10.41	--
Interest, 6 percent of overage investment	8.01	--	4.86	--
Fuel and lubricotion	8.00	--	6.80	--
Repoirs, 25 percent of depreciation	4.28	--	2.60	--
Coble replocement, every 20 doys	2.69	--	1.58	--
Toxes, 2 percent of average investment	2.67	--	1.62	--
Subtotol	42.78	5.34	27.87	3.48
Labor:				
3-mon crew	69.68	--	69.68	--
Poyroll overheod (22 percent)	15.33	--	15.33	--
Subtotol	85.01	10.63	85.01	10.63
Totol loading cost	127.79	15.97	112.88	14.11

[1] Clean logging used o 1-yord crowler unit, estimated delivered price new, $53,000. $53,000 minus 20-percent solvoge volue plus estimated cost of fuel tank and radio = $42,830, omount to be depreciated.

Relogging used o 3/4-yard crawler unit, estimated delivered price new, $32,000. $32,000 minus 20-percent salvoge volue plus estimated cost of fuel tank and radio = $26,030, amount to be depreciated.

All calculations are based on 240 operating days per year.

Table 15.—Hauling cost summary in operations in 110-year-old western hemlock near Cosmopolis, Wash., 1961

Item	Miles	Unit cost	Total cost per thousand boord feet
		Dollars	
Rood class A, paved, not over 6-percent grade	12.3	0.155	1.91
Rood closs A-1, continuously maintained gravel, not over 6-percent grode	4.8	.165	.79
Rood closs B, continuously maintoined gravel over 6-percent grade	.5	.220	.11
Basic rate per piece (averoge 43 pieces)	--	.065	2.80
Bosic rate per thousand boord feet	--	--	1.82
Gross cost per thousand board feet	--	--	7.43
Net cost per thousand board feet, with estimoted 5-percent defect	--	--	7.82
Net cost per thousond board feet, with estimoted 12-percent profit and risk removed	--	--	6.88

Source: Washington Utilities ond Transportation Commission rates, adjusted for log defect and profit risk.

GPO 988-375

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Adams, Thomas C.

1965. Economic comparison of relogging and clean logging in mature hemlock. U. S. Forest Serv. Res. Paper PNW-24, 20 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Both relogging and clean logging have the objective of increasing utilization of small material that would otherwise be left on the ground as logging residue. This time and cost study analyzes cost of removing pulpwood as part of the main logging operation (clean logging), as compared with splitting the operation into two stages, using smaller equipment for the pulpwood relogging.

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